Food consumption and utilization of *Hippodamia variegata* (Coleoptera: Coccinellidae) is related to host plant species of its prey, *Aphis gossypii* (Hemiptera: Aphididae)

LI Yan-Yan[1,2], ZHOU Xiao-Rong[1], DUAN Wen-Chang[2], PANG Bao-Ping[1,*]

(1. Research Center for Grassland Entomology, Inner Mongolia Agricultural University, Hohhot 010019, China;
2. Institute of Pomology, Chinese Academy of Agricultural Sciences, Xingcheng, Liaoning 125100, China)

Abstract: 【Aim】 The quality and type of a prey play key roles in selection, consumption and trophic transfer efficiencies by its predators. The nutritional quality of a plant can affect that of the herbivore, which in turn can affect the herbivore's nutritional quality as the prey for predators. In order to further understand the tritrophic interaction among host plants, preys and predators, the effects of the prey's host plant species on the predator were investigated. 【Methods】 The effects of the prey's host plant species on the predator were assessed by studying the consumption and utilization of the cotton aphid, *Aphis gossypii* Glover (Hemiptera: Aphididae), reared on five species of Cucurbitaceae by the 4th instar larvae and female adults of *Hippodamia variegata* (Goeze) (Coleoptera: Coccinellidae). 【Results】 The food consumption was the highest for the 4th instar larvae and the female adults of *H. variegata* when they were fed on the cotton aphids reared on *Cucurbita moschata* var. *melonaeformis*. The food consumption was the lowest for the 4th instar larvae and female adults of *H. variegata* when they were fed on the cotton aphids reared on *Lagenaria siceraria* var. *gourda*. The relative growth rate (RGR), efficiency of conversion of ingested food (ECI) and efficiency of conversion of digested food (ECD) were the highest for the 4th instar larvae of *H. variegata* when they were fed on the cotton aphids from *Cucumis melo* var. *cantalupensis*. The RGR did not differ significantly in female adults of *H. variegata* when they were fed on the cotton aphids reared on *C. sativus* and *C. pepo* var. *medullosa*, while the ECI and ECD did not differ significantly when they were fed on the cotton aphids reared on *C. sativus*, *L. siceratia* var. *gourda* and *C. pepo* var. *medullosa*. Therefore, the cotton aphids reared on *C. melo* var. *cantalupensis* are more suitable preys for the 4th instar larvae of *H. variegata*, whereas those reared on *C. sativus*, *L. siceratia* var. *gourda* and *C. pepo* var. *medullosa* are more suitable preys for the female adults. 【Conclusion】 The predation efficiency of *H. variegata* on the cotton aphids is related to the host plant species. This result makes a theoretical foundation for further using the feeding habits of an insect to control insect pests.

Key words: *Hippodamia variegata*; *Aphis gossypii*; host plant; tri-trophic interaction; food consumption and utilization

1 INTRODUCTION

The quality and type of a prey play key roles in selection, consumption and trophic transfer efficiencies by predators (Michaud, 2000; Katsarou *et al.*, 2005). For example, the nutritional quality of a plant can affect the herbivore, and in turn can affect the herbivore's nutritional quality as the prey for predators. Prey quality has been demonstrated by feeding predators on the prey reared on different diets (Francis *et al.*, 2001; Al-Zyoud *et al.*, 2005). The growth and survival rate increased when the wolf spider, *Pardosa amentata*, was fed on the fruit flies reared on a nutrient-rich medium (Mayntz and Toft, 2001). The congeneric species *P. milvina* killed similar numbers of fruit flies reared on either a high or low quality diet, but ingested much more than the latter (Schmidt *et al.*, 2012). Thus, insights into predator-prey interactions can be gained by understanding how the quality of a prey affects its consumption and utilization by the predator.

Quantitative nutritional approaches can be used to measure food consumption and utilization. Such indices include the consumption index (CI), relative growth rate (RGR), approximate digestibility (AD), efficiency of conversion of digested food (ECD) and efficiency of conversion of ingested food (ECI) (Chown and Nicolson, 2004).

基金项目: 内蒙古自然科学基金重点项目(20080404ZD05)

作者简介: 李艳艳, 女, 1986 年 6 月生, 内蒙古呼伦贝尔市人, 博士, 助理研究员, 研究方向为昆虫生态学, E-mail: lyy4455@hotmail.com
* 通讯作者 Corresponding author, E-mail: pangbp@imau.edu.cn

收稿日期 Received: 2015-04-23; 接受日期 Accepted: 2015-08-20

Shobana *et al.* (2010) used these indices to show that the utilization of food by the swallowtail butterfly, *Papilio polytes*, reared on *Citrus medica* and *Toddalia asiatica* was higher compared with other three host plants tested. These indices were also used to show that cabbage was a more suitable host for the cabbage butterfly, *Pieris brassicae*, than other plants tested (Ansari *et al.*, 2012). Although nutritional indices have been used to show how host plant quality affects herbivores, there were few comparable studies that have used these indices to examine the suitability of a prey to predators.

The cotton aphid, *Aphis gossypii* Glover (Hemiptera: Aphididae), is an important cosmopolitan agricultural pest with a broad host range, and transmits many plant viruses that cause substantially greater losses than direct feeding injury (Ebert and Cartwright, 1997). *A. gossypii* has been the topic of numerous studies including life history parameters on different host plants (Perng, 2002), population dynamics in the presence of the ladybird beetle, *Coleomegilla maculata* DeGeer (Rondon *et al.*, 2005), and the aphid's response to temperatures when reared on pepper (Satar *et al.*, 2005).

The ladybird beetle, *Hippodamia variegata* (Goeze) (Coleoptera: Coccinellidae), is an important predator of aphids in numerous field and greenhouse crops (Kontodimas and Stathas, 2005; Golizadeh and Jafari-Behi, 2012). To improve its use as a biocontrol agent, the researches on *H. variegata* have included its biological characteristics (An *et al.*, 2000), life table parameters (Lanzoni *et al.*, 2004; Kontodimas and Stathas, 2005; Wu *et al.*, 2010), functional responses (Jafari and Goldasteh, 2009; Farhadi *et al.*, 2010; Li *et al.*, 2013b) and chemical ecology (Li *et al.*, 2013a). The researches on this and other species of coccinellids showed that the aphid host plants could influence the predator's development and reproduction. Francis *et al.* (2001) showed that the development and adult weight of *Adalia bipunctata* fed on the peach-potato aphid, *Myzus persicae* Sultzer, differed according to the aphid's host plant species.

In this study, we compared the consumption and suitability of *A. gossypii* populations reared on five plant species for *H. variegata*. In previous work, Wu *et al.* (2009) showed that *A. gossypii* reared on these plant species differed in nutritional quality. Farhadi *et al.* (2010) reported that the 4th instar larvae and female adults of *H. variegata* consumed the most prey, *Aphis fabae* (Scolpoli). Other authors got similar results (Feng *et al.*, 2000; Pang *et al.*, 2000; Lee and Kang, 2004). The study from Wu *et al.* (2010) showed that the aphids from five host plant species influenced the development of *H. variegata*. However, we do not know how much the beetles can consume and utilize for their development. Therefore, we further used the 4th instar larvae and female adults of *H. variegata* to determine the influence of five Cucurbitaceae host plant species of *A. gossypii* on food utilization of *H. variegata* in the laboratory.

2 MATERIALS AND METHODS

2.1 Stock cultures

Aphis gossypii was collected from cucumber plants grown in a greenhouse in Hohhot (111°48′ E, 40°49′ N), Inner Mongolia, China. These aphids were used to start five colonies, each reared for at least five generations on either squash *Cucurbita moschata* (var. *melonaeformis* Poitet), cucumber *Cucumis sativus* L., zucchini *Cucurbita pepo* (var. *medullosa* L.), calabash *Lagenaria siceraria* (var. *gourda* Stand) or honeydew melon *Cucumis melo* (var. *cantalupensis* L.). These species were the main hosts of *A. gossypii* in China. For each host species, 3–4 plants were grown in pots (14 cm × 17 cm, 30 pots per species) of nutrient soil mixed with vermiculite (4∶1, m/m). Plants were trimmed to maintain them at a small size with 4–6 mature leaves.

Hippodamia variegata adults were collected from fields of *Medicago sativa* L. at Inner Mongolia Agricultural University, Hohhot, China. Beetles (one male, one female) were held in Petri dishes (16.0 cm in diameter and 2.6 cm in depth) with moist filter paper on the bottom. Beetles were fed on *Myzus persicae* (Sulzer) before experiments. Eggs laid by these beetles were used in this experiment. Host plants and insects were maintained at conditions of 25 ± 1℃, 60% ± 10% RH and 16L∶8D photoperiod.

2.2 Nutritional indices

Newly-hatched beetle larvae (< 24 h) were collected from the laboratory cultures and kept individually in separate Petri dishes as described above. Larvae were daily provided with aphids (50 mg) from five host plants, *i. e.*, *C. pepo*, *C. melo*, *L. siceraria*, *C. sativus* and *C. moschata*, respectively, and the unconsumed aphids from the previous day were removed. In this manner, larvae were reared to obtain the 4th instar larvae and female adults. Using a soft brush, 10 newly-molted 4th instar larvae and 10 females were transferred to individual Petri dishes. Each beetle was starved for 24 h and then provided with 3rd–4th instar larvae of

aphids (80 mg) from one of the five host plant species. Thus, a total of 100 Petri dishes with filter paper were maintained, *i. e.*, (10 4th instar larvae and 10 females) × 5 host plant treatments. We calculated the weight of faeces by weighing the filter paper before and after feeding. The weight of the larvae and the female adults, aphids fed, aphids left uneaten and faecal matter produced were recorded 24 h later using an electronic balance (Sartorius BP211D, precision = 0.01 mg). The indices were calculated using the following formulae (Chown and Nicolson, 2004):

Consumption index (CI): $CI = E/TA$;

Relative growth rate (RGR): $RGR = G/TA$;

Approximate digestibility (AD): $AD = (E - F)/E \times 100$;

Efficiency of conversion of digested food (ECD): $ECD = G/(E - F) \times 100$;

Efficiency of conversion of ingested food (ECI): $ECI = G/E \times 100$.

Where, T = duration of feeding period (days), A = mean fresh weight of prey insect over unit time, E = fresh weight of food eaten, F = weight of faeces, G = fresh weight gain of predator insect during feeding period.

2.3 Data analysis

Nutritional indices of *H. variegata* reared on aphids from different plant species were compared with one-way analysis of variance (ANOVA, critical $P = 0.05$) tests. Mean values were compared with Tukey's HSD *post-hoc* tests. Data were analyzed with the statistical package SPSS 12.0 (SPSS Inc. 2003).

3 RESULTS

3.1 Food consumption, faecal output and weight gain of *H. variegata* on different aphid populations

The source plants of the aphid affected its consumption by *H. variegata* (Table 1). This was true for both 4th instar larvae ($F_{4,45} = 36.298$, $P < 0.001$) and female adults ($F_{4,45} = 16.843$; $P < 0.001$). The food consumption was the highest when the 4th instar larvae of *H. variegata* were fed on the aphids from *C. moschata*, while the lowest when they fed on the aphids from *L. siceraria*. The food consumption was the highest when the female adults of *H. variegata* were fed on the aphids from either *C. moschata*, *C. pepo* or *C. sativus*, while the lowest when the females were fed on the aphids from *L. siceraria*. The food consumption of the larvae was significantly higher than that of the female adults.

The source plants of the aphid also affected the faecal output by *H. variegata* (Table 1). Faecal output did not differ significantly when the 4th instar larvae of *H. variegata* were fed on the aphids from *C. melo*, *L. siceraria* or *C. sativus* ($P > 0.05$), or when the female adults were fed on the aphids from *C. pepo*, *L. siceraria* or *C. sativus*. When the female adults of *H. variegata* were fed on the aphids from *C. pepo*, their faecal output was significantly higher than that of the larvae fed on the same host ($P < 0.05$). When *H. variegata* were fed on the aphids from the other four host plants, the faecal output of the larvae was significantly higher than that of the female adults ($P < 0.05$).

It was observed that the 4th instar larvae of *H. variegata* gained the most weight compared to the female adults on all host plants (Table 1). A significantly higher weight gain was evident when the larvae were fed on the aphids from *C. melo*, followed by those fed on the aphids from *L. siceraria*, *C. sativus*, *C. moschata* and *C. pepo*. The higher weight gain was evident when the female adults were fed on the same aphids from *C. sativus* and *C. pepo*. Average gain weight of the larvae was significantly higher than that of the female adults except feeding the aphids from *C. pepo*.

Table 1 Food consumption, faecal excretion and weight gain and *F* values tested for the 4th instar larvae and female adults of *Hippodamia variegata* fed on *Aphis gossipii* from different host plant species

Host plants	Fresh food consumed (mg)		Faecal matter (mg)		Average weight (mg)	
	4th instar larva	Female adult	4th instar larva	Female adult	4th instar larva	Female adult
Cucumis melo var. *cantalupensis*	29.75 ± 0.32 ab	25.71 ± 0.43 b*	1.06 ± 0.09 c	0.42 ± 0.03 ab*	5.09 ± 0.13 e	0.67 ± 0.04 a*
Lagenaria siceraria var. *gourda*	25.84 ± 0.50 a	22.64 ± 0.38 a*	0.91 ± 0.05 c	0.55 ± 0.09 bc*	3.01 ± 0.21 d	1.20 ± 0.15 b*
Cucumis sativus	29.04 ± 0.33 b	26.99 ± 0.42 bc*	0.96 ± 0.09 c	0.60 ± 0.03 c*	2.44 ± 0.12 c	1.67 ± 0.18 c*
Cucurbita moschata var. *melonaeformis*	32.55 ± 0.50 d	28.02 ± 0.77 c*	0.66 ± 0.05 b	0.39 ± 0.04 a*	1.68 ± 0.11 b	0.99 ± 0.05 ab*
Cucurbita pepo var. *medullosa*	30.60 ± 0.34 c	27.16 ± 0.46 bc*	0.35 ± 0.03 a	0.64 ± 0.03 c*	0.53 ± 0.02 a	1.60 ± 0.05 c*

Data are mean ± *SE*, and the means followed by different letters in the same column indicate significant difference at the 0.05 level by Tukey's test among different host plants. The asterisk indicates significant difference at the 0.05 level between larvae and adults.

3.2 Indices of food utilization of *H. variegata* fed on different aphid populations

Consumption indices (CI) of *H. variegata* also were affected by source plants of aphids for the 4th instar larvae ($F_{4,45} = 3.659$, $P = 0.012 < 0.05$) and the female adults ($F_{4,45} = 11.505$, $P < 0.001$) (Fig. 1). The higher CI value of the 4th instar larvae was recorded on *C. melo*, *C. moschata* and *C. pepo*, and the lowest on *L. siceraria* as compared with those on the other host plants tested. The higher CI value of the female adults was recorded on *C. moschata*, *C. pepo* and *C. sativus* compared with those on the other two plants tested.

Source plants of aphids affected significantly the approximate digestibility (AD) for both 4th instar larvae ($F_{4,45} = 21.543$, $P < 0.001$) and female adults of *H. variegata* ($F_{4,45} = 5.164$, $P = 0.002 < 0.01$) (Fig. 1). The AD value was higher when the 4th instar larvae were fed on the aphids from *C. pepo* and lower when they were fed on the aphids from *C. melo*, *L. siceraria* and *C. sativus*. The AD value was higher when the female adults were fed on the aphids from *C. moschata* and *C. melo* than on those from the other three plants tested.

Relative growth rates (RGR) was also affected by source plants of aphids for the 4th instar larvae ($F_{4,45} = 88.828$, $P < 0.001$) and female adults of *H. variegata* ($F_{4,45} = 18.153$, $P < 0.001$) (Fig. 1). The RGR value was the highest when the 4th instar larvae were fed on the aphids from *C. melo* and the lowest when they were fed on the aphids from *C. pepo*. The RGR value was higher when the female adults were fed on the aphids from *C. sativus* and *C. pepo*, and the lowest when they were fed on the aphids from *C. melo*.

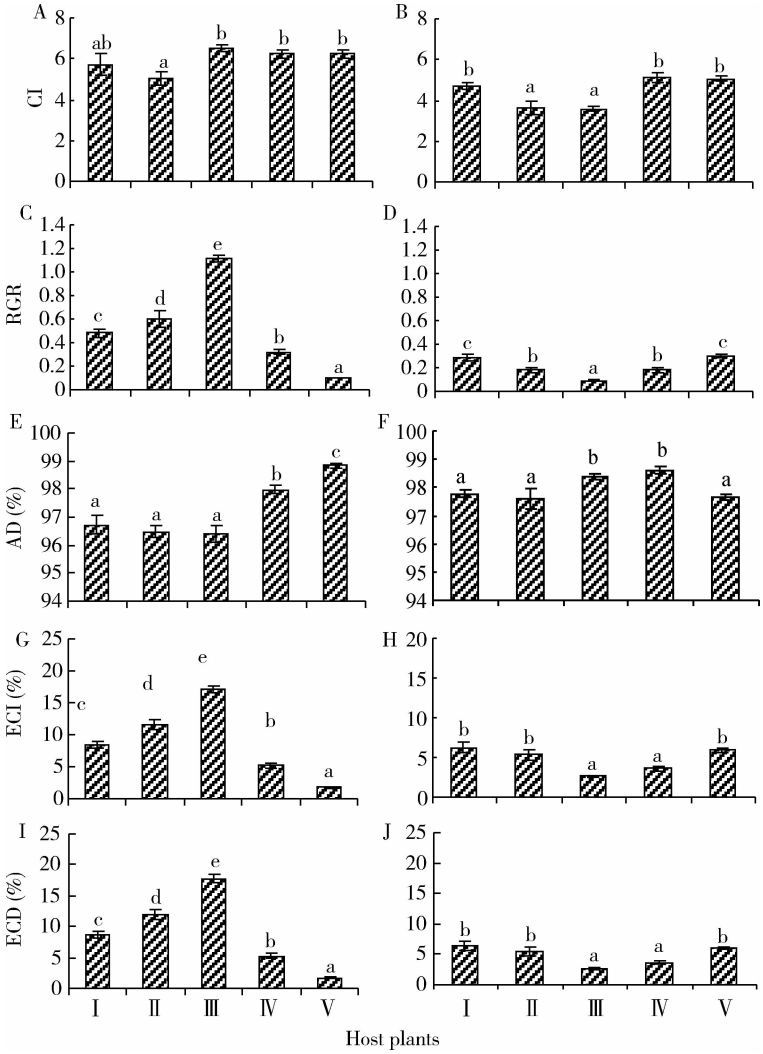

Fig. 1 Indices of food consumption and utilization of *Hippodamia variegata* fed on different *Aphis gossipii* populations from five host plant species

Ⅰ: *Cucumis sativus*; Ⅱ: *Lagenaria siceraria* var. *gourda*; Ⅲ: *Cucumis melo* var. *cantalupensis*; Ⅳ: *Cucurbita moschata* var. *melonaeformis*; Ⅴ: *Cucurbita pepo* var. *medullosa*. A, C, E, G, I: 4th instar larva; B, D, F, H, J: Female adult. CI: Consumption index; RGR: Relative growth rate; AD: Approximate digestibility; ECI: Efficiency of conversion of ingested food; ECD: Efficiency of conversion of digested food. Data in the figure are mean ± *SE*, and different letters above bars indicate significant difference among different host plants at the 0.05 level by Tukey's test.

The ECI values of the female adults ($F_{4,45}$ = 11.604, $P < 0.001$) and 4th instar larvae of *H. variegata* ($F_{4,45}$ = 143.802, $P < 0.001$) differed significantly when they were fed on the aphids from five host plants. The ECI value of the larvae was significantly higher on *C. melo* than on the other four host plant species and the lowest on *C. pepo*. The ECI value was higher when the female adults were fed on the aphids from *C. sativus*, *L. siceraria* and *C. pepo*.

The mean efficiencies of conversion of digested food (ECD) were also significantly different among the 4th instar larvae ($F_{4,45}$ = 138.703, $P < 0.001$) and female adults of *H. variegata* ($F_{4,45}$ = 11.756, $P < 0.001$) on five host plant species of aphids. The ECD value was significantly higher when the larvae were fed on the aphids from *C. melo* and the lowest when the larvae were fed on the aphids on *C. pepo*. However, the ECD values were also higher when the female adults were fed on were the aphids from *C. sativus*, *L. siceraria* and *C. pepo* than from the other two plants.

4 DISCUSSION

Evaluating nutritional indices of a predator was one of the best ways to assess prey quality. Since Waldbauer's excellent review (Waldbauer, 1968), many researchers have begun to use nutritional indices to improve understanding of nutritional physiology and insect ecology (Chown and Nicolson, 2004). The concept of prey quality for a predator should include all aspects of the nutritional value of the prey as food, and it is relevant to the fitness of the predator (Toft and Wise, 1999). In order to attain the ideal growth performance, the predator must obtain necessary nutrients in a suitable prey whose nutrients are affected by their host plants. The analysis of constituents of prey can provide the detailed content of prey, but can tell nothing about its quality. The quality of different preys can be evaluated by comparing the food utilization when they were kept on different diets. It also means that the fitness of a predator can be evaluated without knowledge on nutritional constituents of food.

There were some reports about using the parameters of food utilization to measure the favorite host plants of a herbivore (Xue *et al.*, 2010; Ansari *et al.*, 2012; Hemati *et al.*, 2012). In the current study, the parameters of food consumption and utilization of *H. variegata* fed on aphids from five host plant species were evaluated. The results indicated that the food consumption of the 4th instar larvae was significantly higher than that of female adults. Other studies also reported that the 4th instar larvae of ladybird beetles have the highest prey consumption, and may be considered as the most efficient predatory stage in aphid management strategies (Farhadi *et al.*, 2010; Omkar and Kumar, 2013). The growth of the 4th instar larvae needs more food and nutrients to develop into adults.

Our results showed that the host plant species of the cotton aphid affected significantly the nutritional indices of the 4th instar larvae and female adults of *H. variegata*. However, the food utilization of female adults were not as sensitive as the 4th instar larvae when the beetles were fed on aphids from five tested plants because the *F* values of all indices except CI for the 4th instar larvae were much bigger than those for the female adults among five tested plant species. For the 4th instar larvae, the highest RGR, ECI and ECD were found on the aphids from *C. melo*. This reinforces the suggestion that the aphid from *C. melo* was considered to be the most suitable prey for the survivorship of the 4th instar larvae of *H. variegata* (Wu *et al.*, 2010). For the female adults, the nutritional indices except AD on *C. sativus*, *L. siceraria* and *C. pepo* were usually significantly higher than those on the other two plants, indicating that the aphids from *C. sativus*, *L. siceraria* and *C. pepo* were considered to be the more suitable prey for the development of the female adults of *H. variegata*. This difference may be due to the different nutritional requirements between larvae and adults.

This study showed that different host plant species of the cotton aphid had a significant influence on the food consumption and utilization of *H. variegata*. Other researchers got similar results that the host plant species of a prey could affect the consumption and utilization of food by its predators (Xue *et al.*, 2010; Ansari *et al.*, 2012; Hemati *et al.*, 2012). This may be because the host plant species affect the nutritional quality of the prey. Plant species or cultivars can significantly affect the storage of lipids in aphids (Febvay *et al.*, 1992). The pea aphids, *Acyrthosiphon pisum* Harris, reared on alfalfa stored much more fatty acids than those reared on faba bean (Giles *et al.*, 2002). The five host plant species used in this study affected significantly the nutritional quality of *A. gossypii* for the predator (Wu *et al.*, 2009).

These studies offered knowledge for better understanding the relationship among host plant-prey-predator. It showed that it was necessary to know the interactions among trophic levels for biological control. Knowledge of how host plants of the prey affect the consumption and utilization of food by the predator can help one to select the right host plants for rearing natural predatory enemies in biological

control. The mechanism remains to be investigated.

ACKNOWLEDGEMENTS We thank Dr. Kevin D. Floate, Agriculture and Agri-Food Canada, Lethbridge Research Centre for helpful comments on the manuscript.

References

Al-Zyoud F, Tort N, Sengonca C, 2005. Influence of host plant species of *Bemisia tabaci* (Genn.) (Hom., Aleyrodidae) on some of the biological and ecological characteristics of the entomophagous *Serangium parcesetosum* Sicard (Col., Coccinellidae). *J. Pest Sci.*, 78(1): 25 – 30.

An RJ, Li WX, Zhang JX, Zhang LJ, 2000. Study on bionomics of *Hippodamia variegata* (Goeze). *Journal of Zhelimu Animal Husbandry College*, 10(3): 14 – 16. [安瑞军, 李文秀, 张继星, 张丽娟, 2000. 多异瓢虫 *Hippodamia variegata* (Goeze)生物学初步研究. 哲里木畜牧学院学报, 10(3): 14 – 16]

Ansari MS, Hasan F, Ahmad N, 2012. Influence of various host plants on the consumption and utilization of food by *Pieris brassicae* (Linn.). *Bull. Entomol. Res.*, 102: 231 – 237.

Chown SL, Nicolson SW, 2004. Insect Physiology Ecology: Mechanisms and Patterns. Oxford University Press, Oxford. 16 – 17.

Ebert TA, Cartwright BO, 1997. Biology and ecology of *Aphis gossypii* Glover (Homoptera: Aphidiae). *Southwest. Entomol.*, 22: 116 – 153.

Farhadi R, Allahyari H, Juliano SA, 2010. Functional response of larval and adult stages of *Hippodamia variegata* (Coleoptera: Coccinellidae) to different densities of *Aphis fabae* (Hemiptera: Aphididae). *Environ. Entomol.*, 39(5): 1586 – 1592.

Febvay G, Pageaux JF, Bonnot G, 1992. Lipid composition of the pea aphid, *Acyrthosiphon pisum* (Harris) (Homoptera. Aphididae), reared on host plant and on artificial media. *Arch. Insect Biochem. Physiol.*, 21: 103 – 118.

Feng HZ, Wang L, Xiong RC, Wang B, Ji CS, 2000. A study on the population dynamics and predacious function of *Hippodamia* (*Adonia*) *variegata* (Goeze). *Chinese Bulletin of Entomology*, 37(4): 223 – 227. [冯宏祖, 王兰, 熊仁慈, 王兵, 纪昌盛, 2000. 多异瓢虫种群动态及捕食功能的研究. 昆虫知识, 37(4): 223 – 227]

Francis F, Haubruge E, Hastir P, Gaspar C, 2001. Effect of aphid host plant on development and reproduction of the third trophic level, the predator *Adalia bipunctata* (Coleoptera: Coccinellidae). *Environm. Entomol.*, 30(5): 947 – 952.

Giles KL, Madden RD, Stockland R, Payton ME, Dillwith JW, 2002. Host plants affect predator fitness via the nutritional value of herbivore prey: investigation of a plant-aphid-ladybeetle system. *BioControl*, 47(1): 1 – 21.

Golizadeh A, Jafari-Behi V, 2012. Biological traits and life table parameters of variegated lady beetle, *Hippodamia variegata* (Coleoptera: Coccinellidae) on three aphid species. *Appl. Entomol. Zool.*, 47: 199 – 205.

Hemati SA, Naseri B, Ganbalani GN, Dastjerdi HR, Golizadeh A, 2012. Effect of different host plants on nutritional indices of the pod borer, *Helicoverpa armigera*. *J. Insect Sci.*, 12(55): 1 – 15.

Jafari R, Goldasteh S, 2009. Functional response of *Hippodamia variegata* (Goeze) (Coleoptera: Coccinellidae) on *Aphis fabae* (Scopoli) (Homoptera: Aphididae) in laboratory conditions. *Acta Entomologica Serbica*, 14(1): 93 – 100.

Katsarou I, Margaritopoulos JT, Tsitsipis JA, Perdikis DC, Zarpas KD, 2005. Effect of temperature on development, growth and feeding of *Coccinella septempunctata* and *Hippodamia convergens* reared on the tobacco aphid, *Myzus persicae nicotianae*. *BioControl*, 50(4): 565 – 588.

Kontodimas DC, Stathas GJ, 2005. Phenology, fecundity and life table parameters of the predator *Hippodamia variegata* reared on *Dysaphis crataegi*. *BioControl*, 50(2): 223 – 233.

Lanzoni A, Accinelli G, Bazzocchi GG, Burgio G, 2004. Biological traits and life table of the exotic *Harmonia axyridis* compared with *Hippodamia variegata*, and *Adalia bipunctata* (Col., Coccinellidae). *J. Appl. Entomol.*, 128(4): 298 – 306.

Li YY, Zhou XR, Pang BP, 2013a. Effect of host plants on the functional response of *Hippodamia variegata* (Goeze) to *Aphis gossypii* Glover. *Chinese Journal of Environmental Entomology*, 35(5): 688 – 693. [李艳艳, 周晓榕, 庞保平, 2013a. 瓜蚜寄主植物对多异瓢虫捕食功能反应的影响. 环境昆虫学报, 35(5): 688 – 693]

Li YY, Zhou XR, Pang BP, Han HB, Yan F, 2013b. Behavioral responses of *Hippodamia variegata* (Coleoptera: Coccinellidae) to volatiles from plants infested by *Aphis gossypii* (Hemiptera: Aphididae) and analysis of volatile components. *Acta Entomologica Sinica*, 56(2): 153 – 160. [李艳艳, 周晓榕, 庞保平, 韩海斌, 闫锋, 2013b. 多异瓢虫对瓜蚜为害后植物挥发物的行为反应及挥发物成分分析. 昆虫学报, 56(2): 153 – 160]

Mayntz D, Toft S, 2001. Nutrient composition of the prey's diet affects growth and survivorship of a generalist predator. *Oecologia*, 127(2): 207 – 213.

Michaud JP, 2000. Development and reproduction of ladybeetles (Coleoptera: Coccinellidae) on the citrus aphids *Aphis spiraecola* Patch and *Toxoptera citricida* (Kirkaldy) (Homoptera: Aphididae). *Biol. Control*, 18(3): 287 – 297.

Omkar, Kumar G, 2013. Responses of an aphidophagous ladybird beetle, *Anegleis cardoni*, to varying densities of *Aphis gossypii*. *J. Insect Sci.*, 13(24): 1 – 12.

Pang BP, Zhao JX, Meng RX, Meng HW, Yi WD, 2000. Predation of *Adonia variegata* (Goeze) on the wheat aphid, *Macrosiphum avenae* (F.): intraspecific interference and space heterogeneity. *Journal of Inner Mongolia Agricultural University*, 21(3): 13 – 17. [庞保平, 赵建兴, 孟瑞霞, 孟焕文, 伊卫东, 2000. 多异瓢虫对麦长管蚜的捕食作用: 种内干扰和空间异质性. 内蒙古农业大学学报, 21(3): 13 – 17]

Perng JJ, 2002. Life history traits of *Aphis gossypii* Glover (Hom., Aphidiae) reared on four widely distributed weeds. *J. Appl. Entomol.*, 126(2 – 3): 97 – 100.

Rondon SI, Cantliffe DJ, Price JF, 2005. Population dynamics of the cotton aphid, *Aphis gossypii* (Homoptera: Aphididae), on

strawberries grown under protected structure. *Fla. Entomol.*, 88 (2): 152 – 158.

Satar S, Kersting U, Uygun N, 2005. Effect of temperature on development and fecundity of *Aphis gossypii* Glover (Homoptera: Aphididae) on cucumber. *J. Pest Sci.*, 78(3): 133 – 137.

Schmidt JM, Sebastian P, Wilder SM, Rypstra AL, 2012. The nutritional content of prey affects the foraging of a generalist arthropod predator. *PLoS ONE*, 7(11): e49223.

Shobana K, Murugan K, Naresh Kumar A, 2010. Influence of host plants on feeding, growth and reproduction of *Papilio polytes* (the common mormon). *J. Insect Physiol.*, 56(9): 1065 – 1070.

Toft S, Wise DH, 1999. Growth, development, and survival of a generalist predator fed single- and mixed-species diets of different quality. *Oecologia*, 119(2): 191 – 197.

Waldbauer GP, 1968. The consumption and utilization of food by insects. *Adv. Insect Physiol.*, 5: 229 – 288.

Wu XH, Zhou XR, Pang BP, 2010. Influence of five host plants of *Aphis gossypii* Glover on some population parameters of *Hippodamia variegata* (Goeze). *J. Pest Sci.*, 83(2): 77 – 83.

Wu XH, Zhou XR, Pang BP, Li YY, Hao JX, 2009. Changes in major body constituents of *Aphis gossypii* Glover (Homoptera: Aphididae) on different host plants. *Acta Entomologica Sinica*, 52 (11): 1249 – 1254. [吴秀花, 周晓榕, 庞保平, 李艳艳, 郝建秀, 2009. 不同寄主植物上瓜蚜体内主要构成成分的变化. 昆虫学报, 52(11): 1249 – 1254]

Xue M, Pang YM, Wang HT, Li QL, Liu TX, 2010. Effects of four host plants on biology and food utilization of the cutworm, *Spodoptera litura*. *J. Insect Sci.*, 10: 1 – 14.

多异瓢虫食物消耗与利用与其猎物棉蚜的寄主植物种类相关

李艳艳[1,2], 周晓榕[1], 段文昌[2], 庞保平[1,*]

(1. 内蒙古农业大学草原昆虫研究中心, 呼和浩特 010019; 2. 中国农业科学院果树研究所, 辽宁兴城 125100)

摘要: 【目的】猎物质量和类型在捕食者食物选择、消耗及营养转化过程中起着重要作用,植物的营养质量影响植食者的营养质量,进而植食者作为捕食者猎物的营养质量。为进一步了解植物-猎物-捕食者三营养层的相互作用,研究了寄主植物对捕食者食物消耗与利用的影响。【方法】在室内评价了多异瓢虫 *Hippodamia variegata* (Goeze) 4 龄幼虫和雌成虫取食和利用 5 种不同葫芦科植物上的棉蚜 *Aphis gossypii* Glover 的效率。【结果】多异瓢虫 4 龄幼虫和成虫均对南瓜 *Cucurbita moschata* var. *melonaeformis* 上的蚜虫取食量最高,而对瓢葫芦 *Lagenaria siceraria* var. *gourda* 上的蚜虫取食量最低。4 龄幼虫取食哈密瓜 *Cucumis melo* var. *cantalupensis* 上的蚜虫时,其相对生长率、食物利用率和食物转化率均达到最大,而雌成虫在取食黄瓜 *Cucumis sativus* 和搅瓜 *Cucurbita pepo var. medullosa* 上的蚜虫时,其相对生长率不存在显著差异,在取食黄瓜、瓢葫芦和搅瓜上的蚜虫时,其食物利用率和食物转化率也不存在显著差异。因此,哈密瓜上的瓜蚜更适宜作为多异瓢虫 4 龄幼虫的猎物,而黄瓜、瓢葫芦和搅瓜上的瓜蚜更适宜作为成虫的猎物。【结论】寄主植物种类与多异瓢虫对棉蚜的捕食效率相关,该结论为进一步利用昆虫的食性对害虫进行控制奠定理论基础。

关键词: 多异瓢虫; 瓜蚜; 寄主植物; 三级营养关系; 食物消耗与利用

中图分类号: Q968　　**文献标识码:** A　　**文章编号:** 0454-6296(2015)10-1091-07

(责任编辑: 赵利辉)